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DURATION AND SPAWNING PERIOD OF TROPICAL CORALS *Acropora nobilis* AND *Pocillopora verrucosa* AT CORAL REEFS OF BARRANG LOMPO ISLAND, MAKASSAR

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ABSTRACT

There have been great quantity of studies in many aspects on coral sexual reproduction, but only few studies on duration and period of reproduction have been explored. Hence, this research was gained to investigate spawning duration and period of *Acropora nobilis* and *Pocillopora verrucosa*; and to analyze the relationship among colonies size, duration and period of spawning and number of mature egg per polyp slice. Divings were made at night to record spawning duration and period directly through one moon cycle. The number of mature egg per polyp slice was determined by histological approach. The results showed that spawning corals occurred at the full and dark moon. In the dark moon phase, spawning duration of *A. nobilis* has longer time (83–142 min) and significantly different to *P. verrucosa* (75–110 min). However, there were no difference of spawning period between species found (*A. nobilis*: 2-3 nights; *P. verrucosa*: 1-3 nights). The relationship among colony diameter to duration and period of spawning and number of mature egg were revealed a significant polynomial. This relatonship showed explicitly that there was a decreasing duration and period of spawning as well as number of mature egg in bigger colony size (elder colony) after passing the reproductive size or age.

Keywords: duration, period, spawning, Acropora. nobilis, Pocillopora verrucosa

INTRODUCTION

Annual mass spawning of scleractinian corals, as seen in Great Barrier Reef (GBR), is a natural spectacular phenomenon. There are 130 species spawning concurrently in a few days after full moon at the end of spring season and it is noted, more than 30 species spawning at the same hour and night in one location (Babcock *et al*., 1986; Willis *et al*., 1985). Multispecies spawning in the tropical area was first reported in Singapore (Guest *et al*., 2002) and indicated that this remarkable phenomenon becomes a characteristic of tropical coral reefs with a small environmental fluctuation (Baird *et al*., 2000; Guest *et al*., 2002).

Spawning period of most coral species are taken place between night to midnight (Harrison *et al*., 1984; Shlesinger and Loya, 1985; Babcock *et al*., 1986; Szmant, 1986). Generally, spawning period happens in one specific period after sunset for each population, and it is consistent from year to year (Harrison *et al*., 1984; Babcock *et al*., 1986).

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Despite the fact that most aspect of coral sexual reproduction has been revealed in some location in the world (Harrison and Wallace, 1990; Richmond and Hunter, 1990; Richmond, 1997) still, there is little information on duration and period of reproduction from a coral population. Therefore, *in situ* observation on reproduction process was carried out to identify duration and period of reproduction of *Acropora nobilis* and *Pocillopora verrucosa*. Otherwise, this research was also intended to investigate the relationship of colony size with duration and period of reproduction and the amount of eggs during final phase from polyp of both species.

METHOD

Time and Place

In situ observation was done in the south-east of coral reefs in Barrang Lompo Island, Makassar (Fig. 1). Observations on duration and period of reproduction were conducted based on moon calendar (Arabic calendar), that is according to moon phase in one cycle from date of January 14th up to February 14th, 2002.

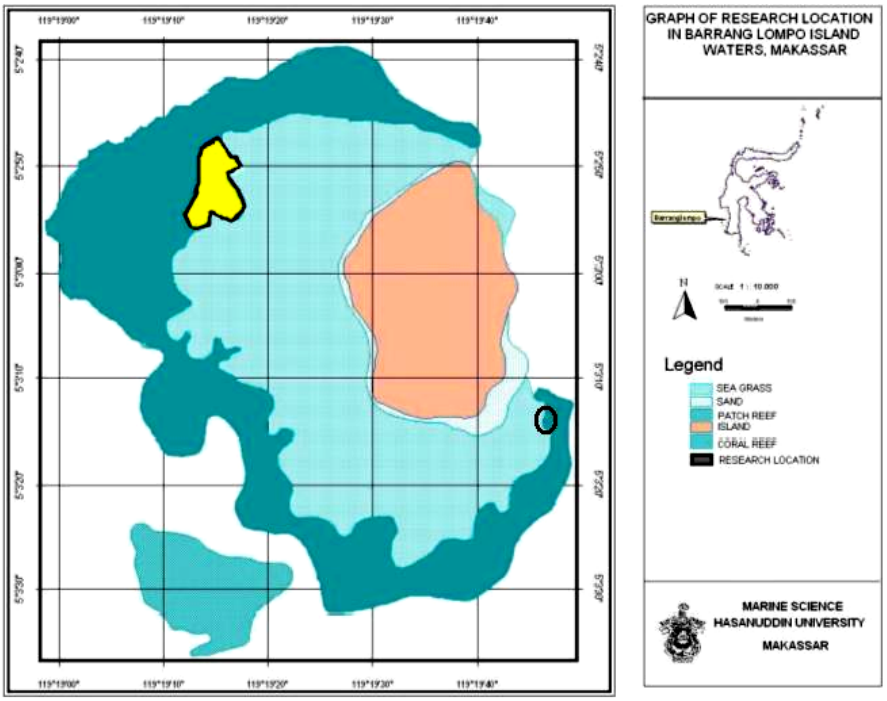

Figure 1. The site of research at Barrang Lompo Island waters.

Histological sampling was conducted in the west side of the island where an abundance population of *A. nobilis* and *P. verrucosa* was found. Based on *in situ* observation, sampling for *A. nobilis* was done one day before full moon (February 25th, 2002) and *P. verrucosa* was done one day before dark moon (March 12th, 2002).

Histological analyze was carried out in the Laboratory of Ecotoxicology and Physiology of Marine Organism, Faculty of Marine Science and Fishery, Hasanuddin University, Makassar.

Procedure

As much as 8–10 observed colonies of both species from south-east side were collected at 4-5 m depth, whereas histological colonies from west side were taken by hammer and chisel at 2-4 m depth. The colonies were directly taken to the *in situ* observational place by a plastic container equipped with aerator. Colony used in this study was a healthy and intact one. They were tagged with plastic plate, which tied on coral branch with steel wire and acclimated for about one month.

Observation was done in the night time diving, briefly after sunset. Diving was conducted during one-month cycle with four moon phases (3-4 days before and after each moon phase) since in low latitude area spawning was happened on many moon phases (Harrison and Wallace,1990; Richmond, 1997). Parameters observed were duration and reproduction period from each coral colony which was reproduced. The duration of reproduction was calculated by writing the time of first and last reproduction of each colony during spawning nights; while the reproduction period was determined by noting the amount of nights for each colony to reproduce. The maximal diameter of each reproduced colony was also measured to study its relation with period and duration of reproduction.

The relationship of total eggs in the final phases (Phase III–IV) and diameter colony was analyzed using histological approach. Determination of total eggs in the final phase was analyzed histologically, that is by taking the middle branch of 50 colonies for each species, in which the diameter were measured beforehand.

Part of the cut branch was fixated in fixative solution (formalin 5-10%; dissolved with sea water) for one week. Afterwards, it was decalcified with 12 N HCl 10% (dissolved with aquades) for 4-6 hours or more (Wallace, 1985; Glynn *et al*., 1991, 1994). Decalcified polyps were placed inside a special basin (tissue cassette) and cleaned with tap water for 24 hours to eliminate the HCl, then placed in a 70% alcohol for a while (Fadlallah and Pearse, 1982; Glynn *et al*., 1994). Histological preparations were set up following a standard procedure (Humason, 1962; Wallace, 1985; Kiernan, 1990; Glynn *et al*., 1991, 1994). The polyp tissue was cut using a microtome with 4–6 μm thickness and was colored using Harris Hematoxiline-Eosin. The middle part of cutting polyp was taken as much as 2–3 slices per slide and the total eggs in the final phase was counted using microscope with 10x, 20x and 40x magnification. Determination of final-phase egg was done based on criterion by Glynn *et al*. (1991, 1994). Polyps, which were counted, were only pieces that had mesentery tissue of more than 50% (Glynn *et al*., 1991). To gain a statistically valid comparison, histological observation were done to 5 polyps for each piece of the branch of different species (Wallace, 1985).

Data Analysis

Data on duration and reproduction period of each species of coral were grouped based on moon phases and presented in the form of table which was further analyzed descriptively. Comparison of duration and reproduction period between species was analyzed using *t-student* test. This statistical analysis was performed on a personal computer with SPSS 9.0.

The relationship between diameter of colony with duration, reproduction period and total final phases egg were analyzed using regression analysis. Only the best model based on correlation value (r) was chosen from various regression models that were performed (linear, logarithmic, exponential and polynomial). The analyses were performed on personal computer with Excel 2000.

RESULT AND DISCUSSION

Duration and Period of Spawning

Natural spawning was observed during night time diving from January 18th to February 15th, 2002 (four moon phase). Throughout those times, spawning was observed during full moon and dark moon (new moon). Time of spawning occurred from evening until before midnight (between 18:00 and 22:00), both at full moon and dark moon. The release of gamete in the full moon phase took place briefly after sunset and continued until before the appearance of moon.

Spawning in the full moon phase was observed for three nights for *A. nobilis* and it happened in the first night until the third night after full moon. On the contrary, *P. verrucosa* did not spawn during those nights. Synchronized spawning (occurred at the same time) from both species was observed for four nights in the dark moon, that was in the first night before dark moon until second night after dark moon. *A. nobilis* colony spawned more intensely during dark moon phase than during full moon phase (Fig. 2).

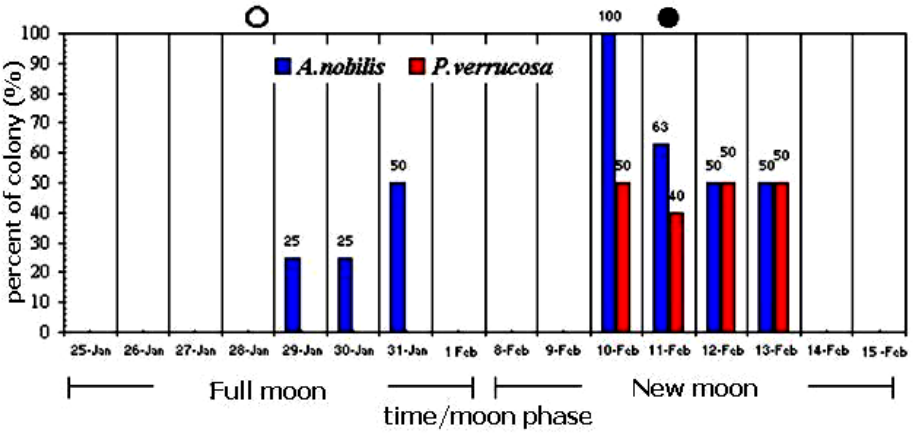

Figure 2. The proportion of coral colony of *Acropora nobilis* and *Pocillopora verrucosa* which spawned every night during full moon and dark moon phase.

Some studies in the high latitude area indicated that spawning nights for most corals, including genus *Acropora* occurred during full moon phase; such as those occurred in five coral reefs in the GBR (Babcock *et al*., 1986), Dampier Island and Houtman-Abrolhos in Western Australia (Babcock *et al*., 1994) and in Okinawa, Japan (Richmond and Hunter, 1990). From low latitude area such as in Central Pacific (Guam, Marshall and Palau) and Red Sea, some species of corals spawned during dark moon phase (Richmond and Hunter, 1990). Period of reproduction of family Pocilloporidae in some coral reefs location around the world, showed a consistency of reproduction time according to moon phase, that was happened during dark moon for both species which spawned and brooded (Harrison and Wallace, 1990; Richmond, 1997).

Night time spawning during dark moon and full moon would minimized predation from predators which relied on light for finding food (visual feeders), such as fish species of plankton feeders (*Abudefduf, Neopomacentrus* and *Pomacentrus*) (Babcock *et al*., 1986). Longer dark phase in dark moon compared to full moon (spawning only took place before appearance of moon) was suspected to be the main reason synchronized spawning occurred for both *A. nobilis* and *P. verrucosa* or other corals in Barrang Lompo Island.

At dark moon phase, when both population spawned massively and synchronize, *A. nobilis* had duration and spawning period relatively longer than in full moon (Table 1). There was still little information on duration of reproduction from a coral population when mass spawning night occurred. There was one report on spawning duration from coral population of *Goniastrea favulus* in GBR which happened for as long as 155 minutes from 18:25 to 20:50 (Babcock *et al*., 1986). Report from Willis *et al.* (1985) and Babcock *et al.* (1986) had only noted down the time of first spawning of coral population in GBR (counted duration during sun down); however, they did not write down the time of spawning ended. Therefore, this research would be the first report which illustrated spawning duration of *A. nobilis* and *P. verrucosa*, 39–142 and 75–110 minutes respectively.

Table 1. The mean of duration and spawning period for *Acropora nobilis* and *Pocillopora verrucosa* during full moon and dark moon phases at coral reefs of Barrang lompo Island, Makassar.

Variables	Moon Phases	Stat.	*A. nobilis*	*P. verrucosa*	t-stat.	Prob.
Spawning duration (min)	Full Moon	Range Mean 2SE (n)	39–115 85.25 22.43 (8)	-	-	-
	New Moon	Range Mean 2SE (n)	83–142 111.86 7.18 (21)	75–110 90.00 4.16 (19)	5.14 (df:38)	$p<4.28x10^{-6}$
Spawning period (night)	Full Moon	Range Mean 2SE (n)	1 1 0 (8)	-	-	-
	New Moon	Range Mean 2SE (n)	2–3 2.63 0.37 (8)	1–3 2.22 0.56 (9)	1.18 (df:15)	p=0.1286

In coral reefs at Barrang Lompo Island, spawning period of *A. nobilis* was only 1–3 nights. This range was shorter compared to those in GBR, that was last 3–5 nights and for *A. nobilis* occurred for as long as 5 nights in a row between October 23rd to 27th of 1983 (Babcock *et al*., 1986). Some possible reasons for this difference were:

1. Difference on energy concentration for reproduction. In this case, time of reproduction in the low latitude/tropical area, was longer in some months and many moon phases, such as those in Red Sea (Shlesinger and Loya, 1985), Caribbean (Szmant, 1986), Micronesia (Richmond and Hunter, 1990) and Japan (Hayashibara *et al*., 1993), and with shorter period of gametogenesis. Longer period of reproduction and shorter gametogenesis process caused energy resource to disperse during reproduction period. In contrast, at GBR or higher latitude area where the period of gametogenesis was longer, about 10 months for eggs (Babcock *et al*., 1986; Harrison and Wallace, 1990; Richmond and Hunter, 1990). Reproduction was concentrated at the end of spring through early summer at full moon phase; therefore energy was accumulated on those months. Accumulation of energy on longer gametogenesis process was predicted to yield more eggs (gametes). For comparison, mean fecundity of *A. nobilis* per slice polyp in GBR was 7.7±0.58, higher than in Barrang Lompo, i.e. 5.22±0.8 eggs (Rani *et al*., unpublished). Aside for more eggs produced, longer period of gametogenesis process may also produce larger size of gametes. Increasing size of eggs tend to correlate with longer period of oogenesis in coral (Harrison and Wallace, 1990). For example, mean diameter of eggs for *A. nobilis* in Big Broadhurst Coral, East Australia was 5.71 μm, max. 696 μm, on the other hand in Barrang Lompo was 321 μm, max. 674 μm (Rani, unpublished).

2. Difference on degree of synchronization on gametes maturation. Coral gametes in tropical area has overlapped in their gametogenesis cycles and this was proved by having various maturity levels in one colony (Bachtiar, 2001), while in GBR, gonad maturity occurred at the same time (synchronized) (Babcock *et al*., 1986) hence more eggs were produced during spawning nights. More gametes, by itself, needed more time in reproduction period and probably also duration of reproduction; and
3. One of the interactions from both factors above.

Particularly for coral *P. verrucosa*, there was no any note concerning period of reproduction both for spawning and brooding as a comparison to this research. Consequently, this research also become the first note regarding period of reproduction of *P. verrucosa*, i.e. occurred for as long as 2–3 nights during dark moon phase.

If comparison has been made between both species of corals, the mean spawning duration of *A. nobilis* (111.86±7.18 minutes) was longer and statistically different ($p<4.28.10^{-6}$) than *P. verrucosa* (90.00±4.16 minutes) (Table 1). Reproduction behavior appeared to be the reason for longer spawning duration in *A. nobilis*. The gametes were arranged and released from polyp's mouth in the form of egg-sperm packet termed as egg-sperm bundles. According to Babcock *et al*. (1986), this gametes arrangement took place under the mouth and needed time between 20–60 minutes, on the other hand the release of *P. verrucosa* gametes occurred separately between egg and sperm and released freely into the water column by fast pulling with a brief preparation period.

Despite the fact that spawning duration showed significantly different mean, still period of spawning did not differ (p=0.1286) between both species (Table 1). This likeness was predicted related to the time of gametes relief from a colony. Spawning nights of *P. verrucosa* was not occurred consecutively but experiencing one night rest during the period. The release of *A. nobilis* gametes was different which in general reproduced in 2–3 nights successively.

The Relationship of Duration and Spawning Period with Colony Size

Graph of functional relation between colony size with duration and spawning period can give a picture of relationship pattern between both parameters with colony size. The best fitted pattern based on correlation value was polynomial, both for duration and spawning period. This functional relationship was significant ($p<0.05$) to both species of corals and showed that duration and spawning period were influenced by colony size (Fig. 3). The correlation value for colony size with duration and spawning period for *A. nobilis* were r=0.83 (p=0.00003) and r=0.91 (p=0.0137), and for *P. verrucosa* were r=0.78 (p=0.00005) and r=0.90 (p=0.0077), respectively.

The significant pattern of relationship of colony size with duration and spawning period affirmed that duration and spawning period of corals increase with increasing size of colony. This increase would reach the maximum period to a certain size of colony, and would decline with increasing size. The pattern could also be interpreted as when the coral spawned for the first time (earlier age), the duration and spawning period would be shorter and this would increase with older age (colony size) and decreased as the coral aged. The range of colony size which had longer duration and spawning period was 35–45 cm (*A. nobilis*) and 35–55 cm (*P. verrucosa*) (Fig. 3).

Duration and spawning period were not only related to time and behavior during the release of gametes, but were also related to total eggs (fecundity) inside the polyp. Hence, this research was also revealed the relationship of colony size with mean total final egg per cutting

polyp. Polynomial pattern was best described the relationship between both parameters with significantly high correlation value for *A. nobilis* and *P. verrucosa*, i.e. r=0.8177 (p=6.99x10^{-9}) and r=0.7785 (p=4.97x10^{-9}), respectively (Fig. 4). This pattern gave an illustration of total final phase eggs inside the polyp that were significantly influenced by colony size.

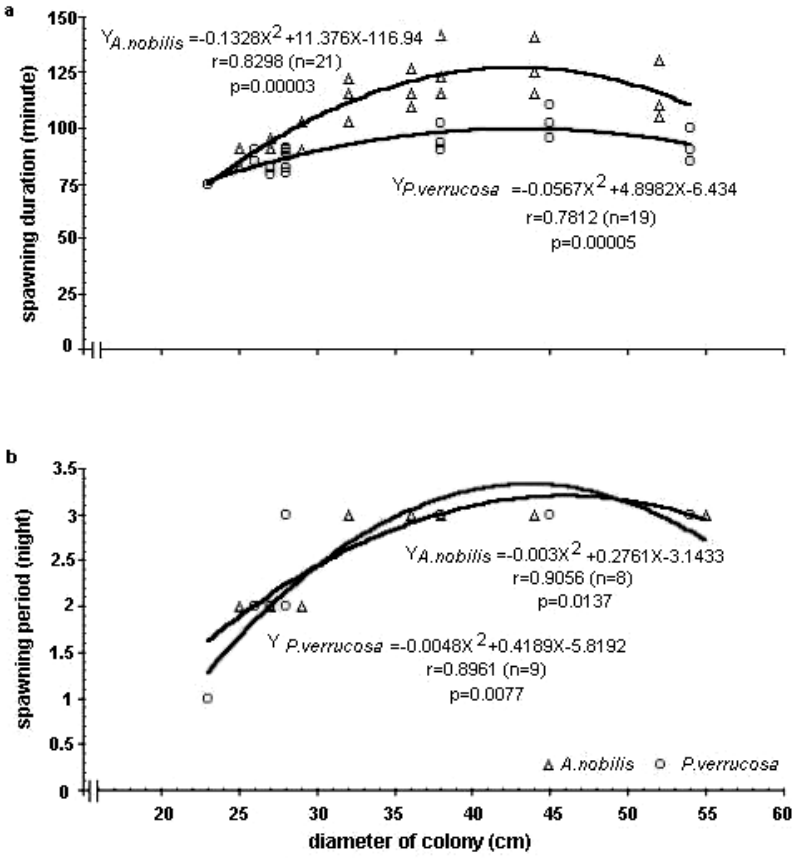

Figure 3. Functional relationship between colony size with spawning duration (a) and spawning period (b) for *Acropora nobilis* and *Pocillopora verrucosa*.

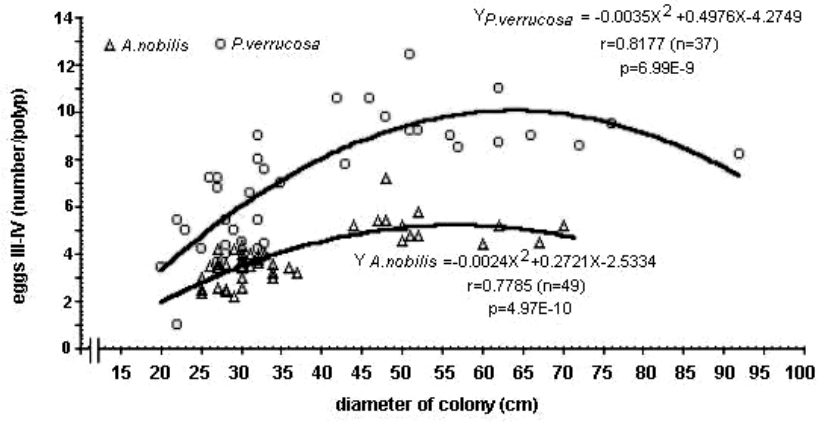

Figure 4. Functional relationship between diameter colonies with total matured egg (III–IV) per cutting polyp in *A. nobilis* and *P. verrucosa*.

The relationship pattern between diameter colony and the amount of egg (Fig. 4) has a similar pattern with the relationship of diameter colony with duration and spawning period (Fig. 3). This similarity, indirectly, showed that duration and spawning period in coral species were determined by the amount of matured egg (fecundity) which ready to be spawned, that was the more matured egg inside the polyp the longer the duration and spawning period.

The relationship of diameter colony and total matured egg inside a polyp (Fig. 4) affirmed that in the early phase of reproduction, total eggs in a polyp was relatively fewer and increased with increasing age (colony size) and in a certain size total egg was maximal and decreased with age. According to Babcock (1988), fecundity can be varying in one life cycle of coral species, which is during pre-reproduction phase, adolescent, adult and older phase. For example in *Goniastrea favulus*, *G. aspera* and *Platygyra sinensis* demonstrated a fast increase in total colony fecundity after reproduction age was reached; this was as a result of combination of increasing polyp fecundity and increasing colony area. Total reproduction was then decreasing in several older classes because fecundity decreased in a surface area on older skeleton. The same thing was also found in *Porites astreoides* which experienced an increase in planula that was released from parent colony after reaching the size of >100 cm^2 and decreased when reached the size of >300 cm^2 (McGuire, 1998). The colony size which had a large number of final phase eggs were 40–55 cm for *A. nobilis* and 40–65 cm for *P. verrucosa*. This size range was relatively similar to the size colony which had longer duration and spawning period.

Other than having various fecundity according to colony size and age, variability could also be happened in colony, between colony, between year and between polyp sizes. This phenomenon related to age and growth, such as those found in *Acropora* spp. (Wallace, 1985), *G. favulus*, *G. aspera* and *Platygyra sinensis* (Babcock, 1988).

CONCLUSION

Spawning of *Acropora nobilis* in Barrang Lompo Island occurred on full moon and dark moon phase (more intensive in dark moon phase); while in *Pocillopora verrucosa* was only happened during dark moon phase. Spawning duration of *A. nobilis* (range 83–142 minutes, mean 111.86 minutes) was significantly longer than *P. verrucosa* (range 75–110 minutes, mean 90 minutes). However, spawning period from both species was not different, i.e. 2–3 nights (mean 2.3 nights) for *A. nobilis* and 1–3 nights (mean 2.2 nights) for *P. verrucosa*. The relationship of diameter colony with duration and period of reproduction and total final phase egg per cutting polyp was significant with polynomial pattern. This model affirmed that in the earlier reproduction phase, that was smaller colony size or younger age, the duration and reproduction period was shorter (fewer total matured egg per cutting polyp) and this period was longer up to a certain age and colony size, and then the period was decreasing in bigger colony size with older age.

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